Design and Measurement of a Four-port Device Using Left-handed Metamaterials

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A left-handed metamaterial can be designed such that the frequency dispersive nature of the constitutive parameters results in a change in the sign of refraction with frequency for a specified incidence angle [1]. A four-port device is designed that utilizes this property and reflection to separate an signal incident from port 1, into three distinct bandwidths. Power transmitted at the metamaterial interface is later collected at a port corresponding to either positive or negative refraction accordingly (ports 3 and 4). Power in the band of frequencies where the dominant effect is reflection is collected at a third output port (port 2).

Designing the device requires the selecting of an appropriate metamaterial that will support negative refraction in some bandwidth, and positive refraction in another. The incidence angle should be selected such that these properties can be realized, and a third band exists where reflection is dominant. Because the energy transmitted into the metamaterial must also exit the metamaterial before being detected at either of the two transmission ports, the geometry affecting the exit angle must also be considered and specified. Ideally the transmitted power exits the metamaterial with minimal internal reflection and is directed directly towards the appropriate port.

We present a design of the four-port device that utilizes the split-ring resonators introduced in [2]. This structure can achieve a Lorentz type dispersion relation [3]. The rings are all oriented in the same direction resulting in dispersion in one component of the permeability tensor. The ring design dimensions are supplied from [4] and the dispersive behavior is verified by simulation followed by applying the retrieval algorithm in [5]. After investigating and specifying the design parameters we find that a wedge of the material can be fashioned to achieve the desired properties. The device is constructed for measurements inside a parallel plate waveguide. Measurements are taken at the edge of a parallel plates utilizing SMA to X-band waveguide adapters. The X-band corresponds to the resonance region of the split-ring resonators. Measurements are made on a vector network analyzer and are found to be consistent with analytical expectations.

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